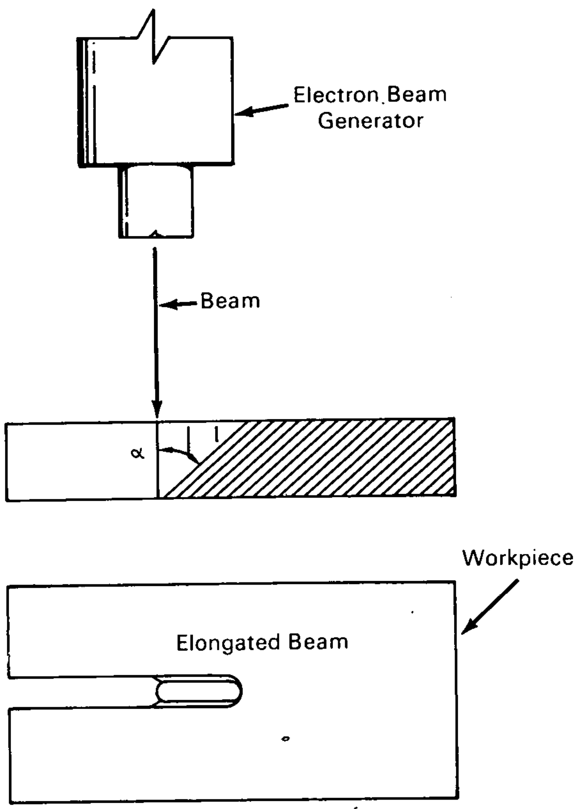
NASA TECH BRIEF

Improved Electron-Beam Welding Technique



Formation of an Inclined Weld-Front with an Electron Beam

In electron-beam welding, the projected beam and the workpiece are moved relative to each other to produce the welded joint. Either the beam is moved along a stationary workpiece or the workpiece is moved under a stationary beam. An electron beam, even of very high energy density, can penetrate the workpiece only a very short distance–of the order of several hundred microns. To produce a joint of appreciable penetration, the usual practice has been to maintain the beam at a sufficiently high energy density to vaporize material along the joint being welded. The beam then penetrates through the vapor and produces a channel filled with vapor which becomes liquid and solidifies after the beam has moved to a succeeding position. A beam channel or hole is formed at the start of the welding seam and for this reason, the process has been called the "key-hole" process. The "key-hole" process has the disadvantages that it requires high beam energy and high energy density. The energy density must be sufficient not only to melt the material at the joint but also to vaporize it. While the power cost to achieve this high energy must be considered, a more important factor is that the high energy, which the incremental parts of the joint receive from the beam, produces imperfections in the weld by reason of variations in beam power and small inhomogeneities in the work. In fact, it has been realized that in order to produce high-quality welded seams, a delicate balance must be maintained between beam-power input and the melting vaporization rate of the work, i.e., welding speed.

It has been demonstrated that by relying on the mobility and the hydrodynamic properties of the material when it is in a liquid phase, an electron beam generator can be used to produce high quality welds without vaporizing the workpiece material; the liquid phase state permits more beam energy to be transferred to the weld-front. The welding is accomplished with the electron beam impinging on the workpiece and the beam and workpiece moving relative to each other.

The power density of the beam, relative to the speed of the workpiece, is such that the material is melted but not vaporized; thus, an inclined weld-front, shown in the figure, is produced. The angle of inclination of

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the weld-front depends on the diameter of the beam on the workpiece and the desired depth or penetration of the weld (usually the depth is 100% penetration). At the start of a weld, there is slight vaporization of the workpiece and at the end, the weld terminates in a sloped crater (if stopped before the end of the metal part is reached) or in a sloped notch. At successive regions of the melt-front, the liquid work material moves out of the path of the beam so that the beam progressively impinges on unmelted material.

The electron beam may also be swept back and forth along the direction of movement of the workpiece by applying an oscillatory voltage to the control coils. This produces, in effect, an elongated beam with a substantially higher angle of inclination, α, than for an axially symmetric beam.

Several hundred welds were made in the described manner to improve this weld technique. The welds were made with the electron beam generator set to project an axially symmetric beam pattern on the workpiece. The beam voltage was set at 150 kV and the beam power was at different magnitudes (3, 4, 5 and 7 kW) for different sets of welds. The beam power was measured with a Faraday cup; scatter losses, created by gas in the beam-transfer column, were found not to affect the beam power which produced the weld. Most welds were of the bead-through-plate variety made on 2219-T87 aluminum.

Note:

Requests for further information may be directed to:

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Patent status:

Inquiries about obtaining rights for the commercial use of this invention may be made to NASA, Code GP, Washington, D.C. 20546.

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